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An Assessment of Occupational Heat Stress in a Central Utility Plant

Abdoulaye Abdoulaziz
University of Nebraska Medical Center

University of Nebraska Medical Center (UNMC)

MPH Capstone Project:

AN ASSESSMENT OF OCCUPATIONAL HEAT STRESS IN A CENTRAL UTILITY PLANT

By: Abdoulaziz Abdoulaye
Committee members:
Chair: Dr. Chandran Achutan
Member: Dr. Athena Ramos
Member: Dr. Jesse Bell

COLLEGE OF PUBLIC HEALTH
UNIVERSITY OF NEBRASKA MEDICAL CENTER

Abstract

Global climate change has been declared a threat to human health, which includes occupational safety issues. As temperatures continue to increase, heat stress and heat-related illness are occupational safety issues that need to be better understood. Assessments of workplace heat exposures are key to implement appropriate health and safety interventions. This study attempted to assess whether workers' perception of work environment temperature in a Central Utility Plant was associated with heat-stress prevention behaviors. Therefore, we used a questionnaire to collect Central Utility Plant employees' demographic characteristics, data regarding their perceived work environment temperatures, and their behaviors related to preventing heat-related illness in the workplace. Fifteen questionnaires were received from the workers at two Central Utility Plants. Although the sample size was small, our analysis from the Chi-square test showed a statistically significant ($p < .05$) relationship between perceived workplace environments and workers' heat stress prevention behaviors. Most workers (73%) reported that they regularly drank fluids while working. Although temperatures and humidity in the Central Utility Plants were perceived as normal, 86% of the workers were associated with getting thirsty and drinking fluids. In addition, several prevention measures were administered by the employer at the workplace (such as cold drinking water, cooled rest areas, additional breaks, and electric fans) during warm weather days. Although multiple heat mitigation practices were implemented and followed, we still recommend that Central Utility Plant employers continue to disseminate specific heat-related policies and regulations and regular training on heat stress risk and prevention behaviors.

List of Keywords

- ACGIH-American Conference of Governmental Industrial Hygienists.
- FIFO-Fly-in/Fly-out.
- HOTHAPS-High Occupational Temperatures Health and Productivity Suppression.
- IRB-Institutional Review Board.
- ISO-International Standardization Work.
- NIOSH-National Institute for Occupational Safety and Health.
- PPE-Personal Protective Equipment.
- RALs-Recommended Alert Limits.
- RELs-Recommended Exposure Limits.
- WBGT-Wet Bulb Globe Temperatures.

1. Project Description

Continuous increase in ambient temperature increases the risk of occupational heat stress to outdoor and indoor workers (Rowlinson & Ciccarelli, 2016). Previous ecological studies have shown that high temperatures contribute to increased morbidity and mortality in the community (Gao et al., 2018; Jianjun et al., 2014). Most of the extreme heat-related studies have traditionally focused on vulnerable groups; such as the elderly, children, and patients with pre-existing conditions (Schulte & Chun, 2009). High temperatures work-environments place workers at an elevated risk for heat-related illnesses and injuries. The National Institute for Occupational Safety and Health (NIOSH) recommends that worker exposure to heat stress in the workplace is controlled by complying with the Recommended Alert Limits (RALs) and Recommended Exposure

Limits (RELs). Workers may experience heat stress resulting from a combination of external heat from the environments and internal physiologic heat generated from metabolic processes (Jianjun et al., 2013).

Total heat stress is the sum of the heat generated in the body and the heat gained from being exposed to the environment, minus the heat lost from the body to the environment (Zander et al., 2018). To maintain core body temperatures, physiological responses promote the transfer of heat from the body back to the environments (Crandall & Gonzalez-Alonso, 2010). However, high levels of heat may affect the body temperature level required for normal body functions (Deyanov & Ivanova, 2006). With predicted increasing frequency and intensity of heatwaves, and some organizations being reluctant to invest in environmentally friendly new technologies, heat exposure presents a growing challenge to occupational health and safety (Mathee et al., 2010; Jianjun et al., 2013). Previous studies have shown that outdoor workers are particularly vulnerable to heat exposure (Jianjun et al., 2013). Although outdoor workers are more likely to suffer from heat stress, indoor workers in non-air conditioned work environments are also at risk of heat-related illness and injury despite the reduced exposure to sunlight radiation (Jianjun et al., 2013). Therefore, this study intended to assess workplace-related heat exposure in Central Utility Plants, which are considered relatively high-risk work environments, to ultimately provide recommendations for minimizing work-related heat exposure.

2. Literature Review

Global climate change has been shown to increase the prevalence of environmental health risks and is becoming a threat to public and occupational health (Gao et al., 2018). Rising temperatures and more intense heat waves pose an increasing threat to worker health (Im, 2017;

Luque, 2019).There are two sources of external heat exposure in the workplace, these include weather-related and man-made exposures (Jianjun et al., 2013). Intense physical labor and exposure to high temperatures may cause occupational health issues. When heat is not adequately dissipated, acute extreme heat exposure can potentially cause a rise in core body temperatures which may result in heat stress (Crandall & Gonzalez-Alonso, 2010). In addition to adverse health issues, heat stress reduces worker productivity (Zander et al., 2018). Heat-related occupational illnesses may occur when an individual’s total heat load exceeds the capacities of the body to maintain its normal functions, thus increasing the risk of occupational injuries and accidents (Jianjun et al., 2013). Heat-related effects are diverse, ranging from aggravated cardio-respiratory-renal issues to distorted time perception and decision quality (Zander et al., 2018). Chronic workplace heat exposure can also cause long-term adverse health issues such as cardiovascular disease, kidney disease, and mental health disorders (Crandall & Gonzalez-Alonso, 2010). Some studies reported that exposure to extreme heat results in symptoms such as elevated blood pressure and urine gravity, increased recovery heart rates and body temperatures, and increased fatigue (Chen et al., 2003; Kalkowsky & Kampmann, 2006).

Studies conducted in Australia and Europe have shown that most heat stress is mostly manifest through fatigue and headaches (Zander et al., 2018). However, high levels of heat stress are reported to cause symptoms such as dizziness, skin rashes, confusion, and nausea (Zander et al., 2018). Core temperatures elevation and dehydration cause heat stress which potentially compromises occupational safety (Crandall & Gonzalez-Alonso, 2010). A self-administrated survey among 115 Japanese male construction workers during the summer season showed that up to 63.7% of workers reported dehydration and 42.2% reported physical fatigue (Jianjun et al., 2013), both of which have been linked to an elevated risk of accidents and injuries. Other studies reported that the correlation patterns between temperatures and work-related injuries and illnesses may vary by industries, gender, and age group (Mehnert et al., 2002; Jianjun et al., 2013). For instance, a study conducted in Australia reported that control variables such as gender, age, and location had no significant impact on the intensity or level of heat stress (Zander et al., 2018). However, workers under 30 years of age who were assigned more physically demanding work showed more injuries than those in other age groups (Kalkowsky & Kampmann, 2006). Another study of Hong Kong construction workers found that heat-related disorders were highest among 26-35 year old and then decreased with increasing age (Jia et al., 2016). Such findings exhibit a pattern contrary to common beliefs that older age increases the risk of experiencing heat stress.

People with pre-existing poor health are more likely to often experience heat stress than those in better health. A study conducted in Australia showed that workers who reported having a health condition were significantly more likely to report heat stress (Zander et al., 2018). They are more likely to suffer from heat stress-related illnesses during heat waves, and may even die from a high level of ambient temperatures (Zander et al., 2018). However, research in a French stainless steel plant showed that workers who were exposed to heat had 10% higher cardiovascular disease mortality than the control group that was not exposed (Wild et al., 1995). Therefore, the relationship between heat exposure and mortality can be affected by the pre-existing health condition of the workers (Jianjun et al., 2013).

Workplace heat exposure may vary in different occupations, and workers in agriculture, construction, mining, and manufacturing, as well as fire-fighters and armed forces personnel, experience extreme heat (Jianjun et al., 2013). Studies have shown that workers in outdoor and labor-intensive industries were more likely to often suffer from heat stress (Zander et al., 2018). Agriculture is reported to be the sector with the highest risk of heat-related illnesses and injuries (Jianjun et al., 2013). However, manufacturing workers in non-air conditioned indoor workplaces can often suffer from heat stress due to the surrounding hot machines, furnaces, ovens, and molten metal (Jianjun et al., 2013). Despite indoor workers not being exposed to direct solar radiation, exposure to heat and humidity generated from work processes or equipment can increase the risk of heat stress (Nerbass et al., 2017). Indoor working environments can become very hot when cooling and ventilation systems are insufficient or not available (Chen et al., 2003). Even in winter, the temperatures in some manufacturing workplaces ranged from 35.5 to 46.5 degrees Celsius when the outdoor temperatures were only between 14 and 18 degrees Celsius (Chen et al., 2003; Jianjun et al., 2013). It was assumed that workers that spent more time working in outdoor environments develop some degree of acclimatization (Zander et al., 2018). Other studies reported that the level of heat stress is positively correlated with the amount of physical exertion at work (Notley et al., 2019).

To prevent adverse health effects related to heat, employers should properly measure and assess heat stress, engineering, and work practice controls, medical monitoring, and use of heat-protective clothing and personal protective equipment (PPE) (Zander et al., 2018). Studies have documented two clothing properties, thermal insulation, and evaporative resistance, that affect human body heat exchange in warm environments (Gao et al., 2018).

Studies from Australia and Europe documented that nearly 90% of workers reported using cooling or intermittent breaks for their immediate heat relief measures (Zander et al., 2018). To avoid dehydration, drinking water and fluids should be used to compensate for the substantial volume of fluid that is being lost through sweating. Some studies have shown that men were likely to hydrate than women, and men were likely to rest than women (Zander et al., 2018). Women have a lower sweat rate than men, therefore, women are more likely to experience heat stress in hot-dry environments than men (Mehnert et al., 2002). For instance, one qualitative study from South Africa reported that women had difficulties coping with hot environments, especially when they were given labor-intensive work (Mathee et al., 2010). Along with the research in South Africa, other studies have documented that females are at an advantage in humid hot weather due to their higher surface-to-mass ratio, while males are advantaged in dry hot weather due to their higher sweating capacity (Jia et al., 2016). The gender effect was suggested to be related to the type of job men performed and whether the working environments were controlled by air conditioning (Zander et al., 2018).

Workers who perform heavy workloads were likely to take more breaks in hot temperatures and that might reduce productivity (Mathee et al., 2010). As such, It is important to find the most appropriate heat mitigation measures that protect workers while minimizing the impact on productivity. For instance, although resting and cooling in controlled environments can be useful, the use of fans as cooling devices might have a mixed-effects on workers with poor health conditions (Zander et al., 2018). Workers with poorer health conditions need to rest more, hence may cause delays in work chains and productivity loss (Jia et al., 2016). Health screening for labor-intensive jobs or jobs in environments with high average temperatures is important in mitigating health issues related to heat stress (Zander et al., 2018).

Similar heat relief measures are used across different sectors, at least for hydrating and resting (Zander et al., 2018). Although it is expected for workers in labor-intensive industries to rest more often, each sector is affected by workers self-pacing their work and resting. (Zander et al., 2018). Studies were done in Australia and Europe have shown that more educated workers were likely to be aware of heat-related prevention behaviors (Zander et al., 2018). However, the immediate relief measure choices should depend on the workers' demographic and work characteristics, and the climate in the working environments (Zander et al., 2018).

Unlike in dry hot environments, it is difficult to sweat and cool in humid hot environments (Zander et al., 2018). According to previous findings, people are most likely to experience heat-related illnesses and injuries in summer months and hottest parts of a day (Bonauto et al., 2007). Therefore, rehydration with excessive water consumption in very humid hot environments can result in hyponatremia which lowers the level of sodium in the blood resulting in symptoms such as headaches, nausea, and vomiting, lethargy, and confusion (Zander et al., 2018). A combination of heat relief measures involved hydrating, resting, and cooling at the same time is recommended (Zander et al., 2018). Few workers use active cooling practices such as arm immersion cooling and ice slurry because they require resting at the same time (Zander et al., 2018). Most workers would prefer to drink fluids while performing their jobs as resting in very hot conditions without cooling at the same time does not reduce core temperatures (Zander et al., 2018). However, studies have suggested that active cooling (such as air conditioning or fans) with resting is the most effective heat relief measure, particularly in hot and humid environments (Zander et al., 2018).

A long-term strategy of coping with heat stress involves changing jobs for workers who often suffer from heat stress. Studies found that workers who perform physical labor were more likely to change jobs or change locations (Zander et al., 2018). The change in jobs can increase the turn-over rates in some industries leading to an increased problem of attracting new employees in some hardship areas (Zander et al., 2018). For instance, highly mobile workers such as fly-in/fly-out (FIFO) is common in mining companies, and workers end up experiencing heat exhaustion as they never become acclimatized (Zander et al., 2018).

The acclimatization of workers is very important as average temperatures increase over a certain period (Jia et al., 2016). Acclimatization is an important physiological process occurring through epigenetic mechanisms that involve morphological and chemical adjustments (Zander et al., 2018). A healthy worker who is extensively exposed to hot environments can tolerate exposure to weather-related heat stress. Previous studies suggested exposure to outdoor heat to be the most effective way of heat acclimatization, and sports science has shown that maximum level of acclimatization can be attained while training in hot environments for a period of one to two weeks (Zander et al., 2018). Therefore, workers living constantly in hot environments may acquire long-term acclimatization, whereas people new to warm areas must be made aware of the appropriate measure of acclimatization. The acclimatization process for the not-acclimatized worker will involve a gradual-pace job by which regular heat relief measures are taken appropriately (Zander et al., 2018). To ensure the health and safety of work in hot regions, some employers select workers who are likely to be already acclimatized to the heat. However, studies have shown that acclimatization decays rapidly but the potential to acclimatize remains for up to two months and can be recovered within two days (Zander et al., 2018). Therefore, levels of heat stress which may cause health effects will depend on the heat tolerance capabilities of the worker. Employers should implement guidelines for heat relief measures and, work health and safety plans which are specific to varying climates and vulnerable working groups (Jia et al., 2016).

Heat safety guidelines often provide recommendations about conditions in which workers can physically and mentally tolerate heat exposure (Zander et al., 2018). Organizations have the responsibility to inform workers of climatic heat stress while providing knowledge on early warning signs of heat stress (Jia et al., 2016). Recommendations are based on precautionary principles and conservative heat exposure thresholds which are considered safe and manageable for the workers. However, some literature has recommended sector-specific heat safety guidelines to ensure adequate protection of workers (Zander et al., 2018). For instance, the United States (U.S) issues guidance for workers that are not sector-specific whereas countries such as Australia issue guidelines that are sector-specific for workers and also for the general public to protect against heatwaves (Zander et al., 2018).

To evaluate occupational heat stress, four thermal climate factors such as air temperatures, humidity, air velocity, and heat radiation should be measured (Gao et al., 2018). However, it is not straightforward to translate outdoor measurements into the evaluation of indoor workplaces because indoor environments can be different (Błażejczyk, 2014). Since the introduction of the Wet-bulb Temperatures more than 100 years ago, studies have proposed various human thermal climate indices (Gao et al., 2018). Havenith and Fiala (2016) recently reviewed 35 heat stress indices and models, and suggested that simple indices are most popular as the acceptance of complex models seems limited (Gao et al., 2018; Havenith & Fiala, 2016; Katić et al., 2016). No index fully complies with all and sometimes conflicting requirements for simplicity, availability, accuracy, validity, reliability, repeatability, continuous recording, data storage, etc (Gao et al., 2018).

Currently, based on the International Standardization Work (ISO), Wet Bulb Globe Temperatures (WBGT) is commonly used for heat stress screening for both inside and outside workplaces without solar radiation (Gao et al., 2018; Parsons, 2014). WBGT is among the most widely used occupational heat stress indices, and it is recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) (Gao et al., 2018).

Most studies on occupational heat stress have been mainly descriptive and only use air temperatures as a heat stress parameter (Bröde et al., 2018). This study, however, aims at focusing on heat stress assessment in a central utility plant to investigate the relationship between heat stress indices and occupational illnesses or injuries.

3. Methods

This study involved descriptive research strategies to determine whether workers' perception on work workplace temperatures in Central Utility Plant was associated with heat stress prevention behaviors. This method was deemed most appropriate for using quantitative data to describe the association between the variables.

3.1 Research location and measures

The study was conducted in two Central Utility Plants located at the University of Nebraska Medical Center (UNMC). The Central Utility Plants operate steam-fired chiller and boiler systems that provide heating, cooling, and often electricity for the need of several facilities. Central boiler systems generate a heating medium, such as steam, at higher heat which may increase the temperatures in the working environments. The study focused on the Central Utility Plant workers and we targeted a total of 22 employees including engineers and technicians directly involved in operational activities.

Variables involving demographic and work characteristics were measured based on their distribution in the workplace. The measurements included both nominal and ordinal scales with scores ranging from “1” (lowest) to “5” (highest). For instance, fatigue level was scored from “1” to “5” with “1” being the lowest fatigue levels and “5” the highest levels. Most variables of pre-existing health conditions were dichotomous with “yes” or “no” type of answers. The independent variables were operationalized as the workers’ perception of their work environments. The dependent variables involved workers’ heat-related prevention behaviors.

3.2 Survey

We used a questionnaire to collect primary data from Central Utility Plants workers. The questionnaire included both open-ended and closed-ended questions. The content and design of the questionnaire were guided by a validated survey tool from the High Occupational Temperatures Health and Productivity Suppression (HOTHAPS) program and other empirical assessments related to heat exposure impact on health (Nunfam, 2020; Sheridan, 2007; Xiang et al., 2015). The questionnaire involved items regarding workers’ demographic characteristics, adaptation behaviors, perception of health-related illness, and heat-stress training needs.

The paper-based survey was provided to workers with the first page containing a brief description of the purpose of the study, and assurance that the data collected was non-identifiable, confidential, and used for research purposes only. Contact information of the principal investigators was available on the questionnaire for further explanation if needed. Before data collection, the University of Nebraska Medical Center's Institutional Review Board

(IRB) was consulted. As per the feedback received from the IRB, approval was not required for our study.

3.3 Data Analysis

Data were processed with Microsoft Excel version 2016 and IBM SPSS Statistics 26 by performing a descriptive analysis to determine the association between workers' perception of workplace temperatures and their behaviors in preventing heat-related illnesses. We used the frequency and cross-tabulations to describe the distribution of Central Utility Plant workers' demographic and work characteristics. We focused on the rating of perceived thermal sensation and thermal comfort, perceived physical exertion, and prevention behaviors by using a chi-square test ($\chi 2$) to determine their association. However, we collapsed variables for perceived temperatures, humidity, and thirst levels to comply with the chi-square test assumption of at least 20% of the observed value in each cell being greater than five.

4. Results

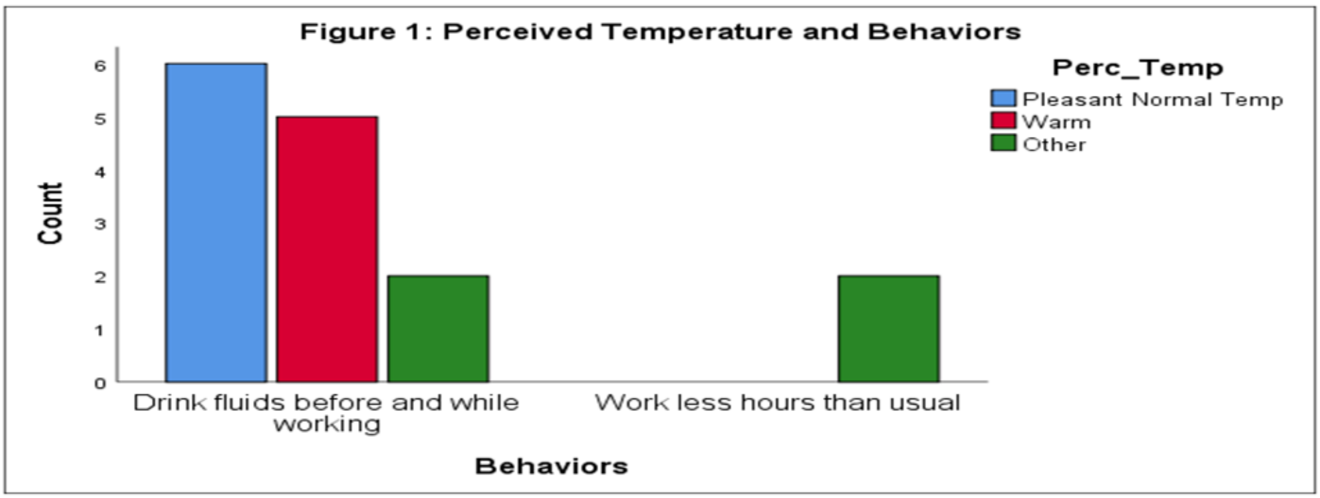
Based on their willingness and interest to participate in the study, 15 workers completed the questionnaire. Results for demographic and work characteristics are summarized in the table below. All study participants were males and their ages ranged from 31 years to 63 years with 53% over the age of 50 years. All respondents had some technical or vocational training and most of the workers had more than 11 years of working experience. Concerning the workload, most responses ranged from moderate to heavy tasks. On a scale from one to five, workers reported an average fatigue levels of 3.07 and a standard deviation of 1.33. In terms of the perceived comfort, 46% described their heat-related discomfort levels as little. Regarding work-related fatigue, 46% of workers reported high fatigue levels. Concerning heat illness concerns, 33% of the participants mentioned that they are very much concerned. All workers reported that they have never experienced heat-related illnesses. In terms of the pre-existing health conditions, one worker reported having heart disease and was taking medications for the ailment. Most workers reported using multiple protection measures to reduce exposure to heat.

In terms of the perceived workplace temperatures, 40% of participants described their environments as pleasant or normal. Similarly, 26% of workers perceived their workplace as slightly humid and the same proportion perceived their environments as pleasant or normal. Sixty percent of workers reported that they get thirsty while working. More than 73% of the participants reported that they drink fluids regularly while working.

Table: Background characteristics of CUP workers (n = 15). F, frequency; %, percentage.

Characteristics	F	%	Characteristics	F	%
Age group		-	**Heat-related discomfort**		-
30 - 39	2	13.3	A little	7	46.7
40 - 49	3	20.0	A lot	4	26.7
50 - 59	4	26.7	Extremely	3	20.0
			So extreme	1	6.7
60+	4	26.7	**Work-related fatigue**		-
Level of education		-	1 lowest fatigue level	1	6.7
High school graduate	2	13.3	2	4	26.7
Technical/Vocational training	8	53.3	3	3	20.0
Associate Degree	2	13.3	4	7	46.7
Bachelor	3	20.0	5 highest fatigue level	0	-
Job Title		-	**Heat-related behavior**		-
Chef utility management	1	6.7	I Drink When Thirsty	2	13.3
High voltage electrician	4	26.7	I drink fluids regularly while Working	11	73.3
OP Tech	2	13.3	Multiple behaviors	2	13.3
Operator	1	6.7	**Heat illness concern**		-
Senior utilities operator	1	6.7	Not at all	2	13.3
Utilities mechanic III	1	6.7	A little	5	33.3
Utility equipment electrician	1	6.7	Moderately	3	20.0
Utility equipment mechanic	3	20.0	Very much	5	33.3
Years of working experience		-	**Painful cramps Y/N**		-
< 5	2	13.3	Yes	3	20.0
5 to 10 year	2	13.3	No response	12	80.0
11+	11	73.3	Yes improve on days off	3	20.0
Time-off at least 7 days		-	**Flushed Y/N**		-
Yes	7	46.7	Yes	3	20.0
No	8	53.3	No response	12	80.0
Physical Workload			Yes improve on days off	2	13.3
			No improvement in days off	1	6.7
A little	3	20.0	**Diarrhea Y/N**		-
Moderately	8	53.3	Yes	4	26.7
Very much	4	26.7	No response	11	73.3
Frequent body posture		-	Yes improve on days off	4	26.7
Usually sitting	1	6.7	**Fatigue Y/N**		-
Standing, but moving my arms a little	1	6.7	Yes	5	33.3
Standing, but moving my arms a lot	6	40.0	No response	10	66.7
Usually, I am walking	5	33.3	Yes improve on days off	5	33.3
Multiple body postures	2	13.3	**Weakness Y/N**		-
Perceived workplace temperature		-	Yes	2	13.3
Pleasant air or normal	6	40.0	No response	13	86.7
Slighly warm	2	13.3	Yes improve on days off	2	13.3
Warm	2	13.3	**Faint Y/N**		-
Very warm	1	6.7	Yes	1	6.7
Other	4	26.7	No response	14	93.3
Perceived workplace humidity		-	Yes improve on days off	1	6.7
Very humid	1	6.7	**Heart disease**		-
Slighly humid	1	6.7	Heart disease	1	6.7
Peasant or normal	4	26.7	**Heart disease Med**		-
slighly dry	4	26.7	Taking medication	1	6.7
dry	1	6.7	**Health condition severity**		-
very dry	1	6.7	Yes	1	6.7
other	3	20.0	No	8	53.3
Work-related thirst intensity		-	I do not know	3	20.0
I get a little thirthy	5	33.3	**Workplace measures**		-
I get thirsty	9	60.0	Cold drinking water	1	6.7
I get very thirsty	1	6.7	Cooled rest area	1	6.7
			Multiple measures	11	73.3
			No response	2	13.3

The three figures below show the results of the relationship in the prevention behaviors of Central Utility Plant workers and their perceived workplace environments. The cross-tabulation between works' perception of work environments and heat-related illnesses prevention behaviors resulted in statistical significance with a p-value of less than .05. Forty six percent of the workers 'drinking fluids was associated with pleasant temperature while working (Figure 1). Similarly, among 46% of the respondents drinking fluids was associated with dry weather conditions (Figure 2). Finally, 86% of the workers' drinking fluids was associated with getting thirsty (Figure 3).



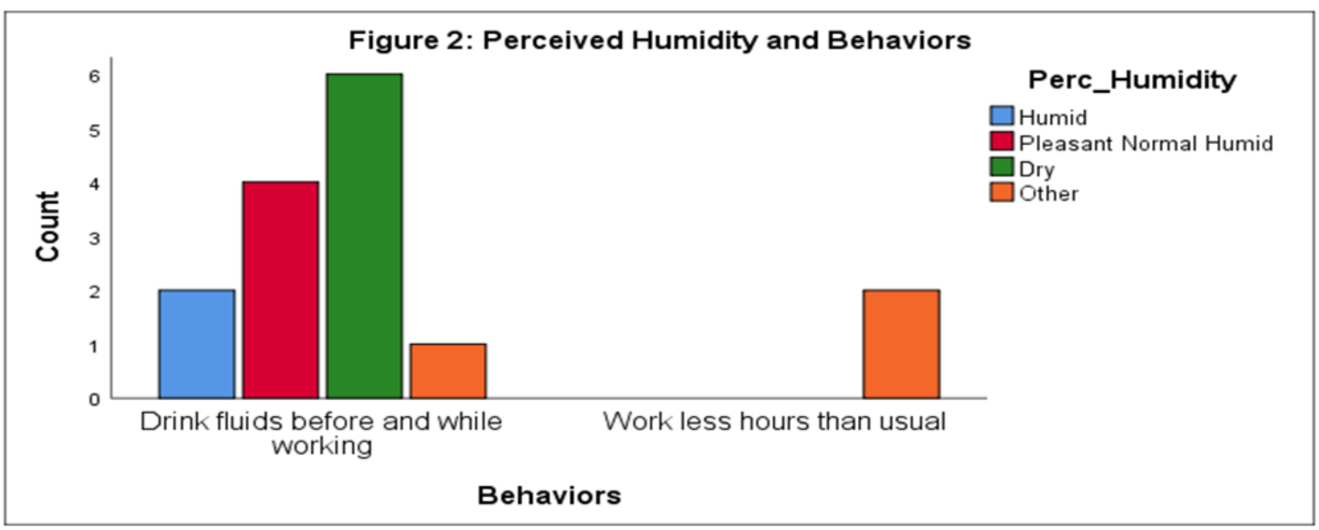
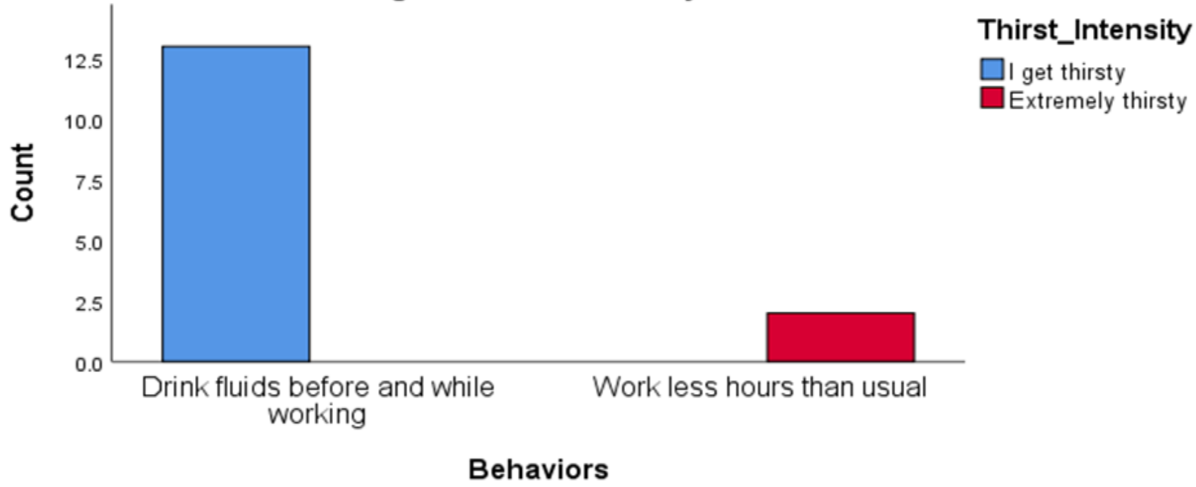


Figure 3: Thirst Intensity and Behaviors



5. Discussion

This study was an assessment of heat-related occupational health in Central Utility Plant workers and our primary aim was to determine the relationship between perceived work environments and coping behaviors. The narrative in our study was based on the results of self-reported questionnaires among Central Utility Plant workers. Similarly, several studies have employed the same method for research design to assess heat-related issues in the workplace (Nunfam, 2020).

We collected background information that involved the demographic and work characteristics of Central Utility Plant workers. We observed that all the participants were males and most of them were above 50 years of age. However, we suspect that the gender inequality in this study was due to our very small sample size. Considering gender in heat-related studies is important as previous studies have mentioned the difference in thermoregulation between males and females (Mehnert et al., 2002). Previous heat stress investigations suggested that heat exposure among women was associated with increased body core temperatures, birth defects and preterm births (He et al., 2016; Mohammadi et al., 2019). Although most of the workers were 50 years of age or older, only one of them reported having cardiovascular diseases and was under medications. However, previous heat stress investigations reported that older workers are at higher risk of heat-related morbidity partly due to their compromised physiological ability to regulate heat (Balmain, 2018). Large studies conducted in Australia and Europe have associated cardio-respiratory-renal diseases with exposure to extreme heat, especially in the older populations (Jianjun et al., 2013). In contrast, another study of Hong Kong construction workers found that heat-related disorders were highest among 26-35 year-olds and then decreased with increasing age (Jia et al., 2016). Therefore, we recommend that Central Utility Plant employers implement medical monitoring programs and hazard control measures for all age groups. Hazard mitigation measures could involve cooled drinking water, reduced workload, intermittent breaks, and regular medical controls. Health and safety programs in the workplace are proven to reduce exposure while increasing worker behaviors in preventing heat-related illnesses (Varghese, 2020). Heat stress training in Central Utility Plants should clearly explain the increased risk of heat stress in older workers. Most of Central Utility Plant workers were educated with technical or vocational training. As previous studies have reported, education increases the extent of workers' attitudes and behaviors related to understanding and implementing prevention measures. Gender, age, and education are important factors that impact the effectiveness of workplace health and safety programs.

Most workers reported that they performed heavy workload which may contribute to high levels of fatigue. However, that might not increase the risk of environmental heat-related illnesses because most workers mentioned a pleasant or normal workplace temperature with little heat-related discomfort. But, previous studies have shown that workers in normal weather conditions were at higher risk of heat-related illnesses as a consequence of their intense workloads (Nerbass et al., 2017; Vega-Arroyo, 2019). Workers' responses related to the temperatures may be bias as our study was conducted in winter. Therefore, it could be challenging for workers to accurately recall their workplace temperatures and their behaviors during warm weather. Using Wet Bulb Globe Temperature (WBGT) index could provide more accurate estimates of heat stress by considering temperatures, humidity, and wind speed measures in the work environments. However, due to the winter, this study did not measure weather variables in the Central Utility Plants. Previous studies have reported that workers were at higher risk of heat exposure during warm weather (Gao et al., 2018; Lamarche et al., 2017)

Most Central Utility Plant workers reported that they implemented many heat stress prevention measures to mitigate their exposure to heat. For instance, most responses involved cooled rest areas, electric fans, additional breaks, and cold drinking water. Such results show that the employers in Central Utility Plants provided heat exposure mitigation measures for the health and safety of the workers. However, Central Utility Plant workers could be at higher risk of heat stress due to their compromised acclimatization to heat. The work in Central Utility Plants required that workers perform tasks indoor and outdoor repeatedly throughout the day. Also, most workers reported that they usually stay away from their work environments for more than seven consecutive days. Studies have argued that leaving the work environments for an extended period increased the risk of compromised acclimatization (Daanen et al., 2018). However, most workers reported that they had work experience of more than 11 years. This extended time spent working in the same environment could accelerate the workers’ acclimatization process. Previous have argued that the potential to acclimatize remains for up to two months for workers who usually work in warm temperatures (Zander et al., 2018). Therefore, we recommend that employers implement administrative controls involving progressive acclimatization by minimizing the period of heat exposures or reducing workload for returning workers and new employees.

The relationship between perceived temperatures, humidity, thirst intensity, and workers' behaviors was statistically significant. Although temperatures and humidity were considered normal, most of the workers reported that they get thirsty. That could be related to the heavy workload and explains why most Central Utility Plant workers reported that they drank fluids regularly while working. However, drinking water could be also linked to social norms in the workplace, as previous studies have associated drinking water behaviors to socio-psychological determinants (Etale, 2018). Although our study results described positive heat-related prevention behaviors implemented by the Central Utility Plant workers, the employers should significantly promote workers' health and safety programs in the workplace that involve the identification and assessment of heat in the workplace, the prevention and control of heat exposure, and workers' participation in heat stress training.

6. Limitations

The major limitation of this study was the small sample size. Therefore, it was challenging to appropriately conduct a statistical test without violating any assumptions. For instance, using Chi-squared and Fisher exact tests were challenging as the data collected could not meet the assumption requirements to get at least 20% of fewer than five counts in each sub-category, and most of our comparisons could not be performed with the contingency 2X2 tables. Therefore, we collapsed the variable sub-categories to achieve better Chi-square tests.

Other limitations involved workers recall bias as the study was conducted in winter. There was a potential risk of workers not accurately remembering workplace weather variables for the last summer when temperatures and moistures levels were at their highest. Winter may not be the appropriate time to measure and assess environmental heat exposure. Therefore, this study did not collect weather variables in workplace environments. Measuring temperatures, humidity, air movement, and heat radiation levels could provide more information about workers' comfort in the workplace.

7. Conclusion

Central Utility Plant workers reported the use of prevention measures based on their perceptions of their workplace temperatures and humidity. The assessment of the Central Utility Plant workers' demographic and work characteristics was determinant to recommend appropriate heat exposure coping strategies. Participants reported that they regularly drank fluids while working and were provided several prevention measures during warm temperatures. Heat-related prevention measured such as drinking cold water, using electric fans, taking additional breaks, and resting in cooled areas were best practices in protecting the Central Utility Plant workers. However, employers should continue to disseminate specific heat-related policies and regulations with regular training on heat stress risk and prevention behaviors. Further study is needed in understanding acclimatization of Central Utility Plant workers who are constantly switching from outdoor to indoor activities.

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